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Discipline and Liquidity in the Market for Federal Funds

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ABSTRACT

I find that high-risk banks pay more for federal funds and are less likely to utilize them as a source of liquidity. The extent of this discipline has risen in recent years, following legislation designed to impose more of the costs of bank failure on uninsured creditors. However, the risk-pricing remains imperfect, and additional results suggest that information problems persist in the fed-funds market. The findings have implications for interest-rate determination, risk contagion in the financial system, the use of market data in banking supervision, and recent efforts to reform Discount Window operations.

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I. Introduction

For most of the past thirty years, monetary policy in the United States has centered, implicitly or explicitly, around a target for the interest rate on federal funds. The decision to focus on this rate poses a unique set of problems. For one thing, the targeting of a market price that the Federal Reserve cannot directly control necessitates some model of how this price responds to variables that it can, such as the monetary base, reserve requirements, and the discount rate. Indeed, economists at the Open Market Desk are continually engaged in precisely this sort of modeling, and the low average inter- and intra-day variation of the effective fed-funds rate around its target is a testament to their skill. On the other hand, the rare but conspicuous occasions on which this rate has significantly missed its mark suggest that the Fed's models remain imperfect.

Additionally—in contrast to yields on Treasury bills and other publicly traded instruments—the concept of a unique fed-funds rate is not well defined. The terms of short-maturity interbank lending contracts are negotiated on a case-by-case basis and can, at least in theory, vary widely in the cross section.[1] The "effective" rate targeted by the Fed is a quantity-weighted average of rates reported by five large brokers, but there is no particular reason to view it as representative, especially given that many fed-funds transactions are not executed through brokers at all.[2] The time-series behavior and macroeconomic determinants of the effective fed-funds rate, at both low and high frequencies, have been studied in detail (see, among many others, Bernanke and Blinder, 1992; Hamilton, 1996; and Hamilton and Jorda, 2002), but little work has been done to analyze the cross-sectional variation underlying the aggregate number.

Banks primarily purchase fed funds to meet reserve requirements (or, more often, a positive target for *excess* reserves), and they are subject to a variety of unpredictable liquidity shocks that determine their need for short-term funding. In a competitive market, however, banks are price takers; systematic liquidity shocks will shift the average price of fed funds, but idiosyncratic shocks should have only trivial effects. This type of behavior, modeled formally by Ho and

Saunders (1985), has frequently been invoked to explain cross-sectional differences in net fed-funds reliance. Such a framework usually contains, at least implicitly, an assumption that there is a single fed-funds rate that applies to all borrowers and, thus, that sellers of fed funds do not consider the possibility that their loans will not be repaid.

Yet a large empirical literature now supports the proposition that the holders of uninsured liabilities at financial institutions demand higher rates of return in response to higher probabilities of default.[3] These studies have almost exclusively focused on subordinated debt and large time deposits, but there is no obvious reason that their logic should not also apply to interbank lending. On the contrary, if market discipline is to occur anywhere on a bank's balance sheet, we might expect it in federal funds. Fed funds are uncollateralized and uninsured, and, given the comparative advantage of banks in understanding the business of banking, it would seem reasonable that they are in a better position than other liability holders to monitor borrowing institutions. Indeed, Calomiris and Kahn (1996) find that banks effectively risk-priced loans to other banks in New England as early as the 1820s. More recently, regulatory reforms in the early 1990s—including the FDIC Improvement Act, the National Depositor Preference Act, and Federal Reserve Regulation F—shifted more of the costs of failure to fed-funds sellers, thus raising the expected costs of fed-funds defaults and providing lenders even stronger incentives for caution.

Anecdotal evidence, such as Austin (2001), indicates that, at least during healthy financial periods, little explicit risk pricing takes place in the overnight market. This may well be rational behavior in an environment where the vast majority of financial institutions are in sound condition and information is costly to discover. The question is whether the prevailing arrangements are capable of identifying the handful of banks—possibly less than 1% of the total—for which failure risk is nontrivial and either indexing the rates on loans to these banks or excluding them from the market altogether. Although not as frequent as losses on other types of liabilities, failure-related losses on fed funds do occur, sometimes with severe consequences for the lending bank. For example, the 1991 failure of the Bank of New England directly triggered the failure of Connecticut Bank and Trust through losses on fed funds sold. A similar situation had occurred in the failure of MCorp two years earlier, which led to the demise of fourteen affiliated institutions. Thus, not only is fed-funds default a possibility, it has more potential than any other bank-liability default to contribute to systemic contagion phenomena. Indeed, the fear of this type of contagion effect was a primary reason for the FDIC's decision to protect uninsured creditors (including fed-funds sellers) of Continental Illinois under the "too big to fail" doctrine. (See Federal Deposit Insurance Corporation, 1998.)

In addition, a look at the institutions involved in the interbank market suggests that the mechanisms necessary for monitoring and discipline are in place. For example, in their surveys of fed-funds activity Goodfriend and Whelpley (1993) and Edwards (1997) both document the possibility of risk pricing (although neither presents evidence on its pervasiveness). Even brokered transactions may adhere to "tiered" pricing schedules, based on bank risk variables. Market discipline may also take place through indirect or non-price mechanisms. Brokers and correspondents do differ substantially in both the rates that they charge and the minimum credit standards they employ. It is therefore natural to expect that, even in the absence of explicit risk-pricing, some adverse-selection-based self-sorting occurs. These credit standards, together with borrowing-frequency guidelines, also present the possibility that discipline in this market operates through rationing.

As cursory evidence of this phenomenon, Table I shows the difference in interbank-funding reliance and pricing between banks that failed and those that did not between 1987 and 2002.[4] This sample includes 1,124 failures, the majority of the post-Depression observations. In the quarters leading up to a bank's failure, there is a clear drop in the ratio of interbank borrowing to total assets, relative to the levels at safe banks. By one year prior to failure, this difference is statistically significant at the 1% level. Although there is less of a clear trend for rates paid on interbank lending—possibly because the highest-risk banks exit the market and so are not observed—the *level* exhibits a statistically significant and persistent difference at least two years prior to failure. These observations strongly suggest that the market responded to the failure risk at these institutions.

TABLE I ABOUT HERE

Outright failure is clearly an extreme case, and the task of this paper will be to see whether these qualitative differences also existed at institutions with lower levels of risk—those that might have failed but did not—once other factors are more carefully controlled for. If, as suggested by the above arguments and the empirical results I present in Section III, bank risk is a non-trivial determinant of fed-funds pricing and reliance, there are several implications for both financial intermediaries and their supervisors.

First, this discussion suggests a link between bank liquidity and other types of risk. Because fed funds are an essential source of liquidity for many banks, the positive risk elasticity of their price implies that risky banks may find themselves with limited access to short-term funding, potentially raising their risk even further. Risky banks face higher costs of borrowing in markets where discipline exists and, all else equal, are more inclined to rely on funding that is not risk priced, such as core deposits and advances from the Federal Home Loan Bank (FHLB).[5] If these sources are exhausted or made unavailable, short-term liquidity shocks will at best substantially raise funding costs and at worst result in bank failure. Such interactions between liquidity and other types of risk have garnered increased interest recently, as government supervisors have come to recognize the limitations of traditional liquidity metrics (see King et al., 2004). On the other hand, if risk is underpriced, lending banks are not adequately compensated for their risks, and difficulties at one bank are likely to spread to others. On an aggregate level, then, the absence of market discipline in the interbank market could theoretically contribute to the transmission of shocks throughout the financial system. This type of contagion effect has been explored, for example, by Rochet and Tirole (1996), Freixas et al. (2000), and Furfine (2003). Underpricing of loans should only occur if lenders are unable to assess the risk of their borrowers at low cost—in other words, if information is imperfect. A number of the tests in Section III are indeed consistent with significant information problems in the fed-funds market.

Second, from a supervisory perspective, the fed-funds market presents a possibility for the use of market mechanisms and market-based data in the surveillance and control of bank risk positions. The idea of using bank-liability prices in supervision has also received considerable attention recently, in the wake of the Basle Accord's entreaty to employ market discipline as one of the "three pillars" of supervision. The Financial Modernization Act (FMA) of 1999 included the latest effort in this direction by experimenting with mandatory subordinated-debt issuance for certain large institutions. A considerable body of research has recently examined the potential for sub debt and, to a lesser extent, uninsured deposits to contribute to banking supervision, either through direct pressure on banks to curtail risk or as a signaling device for supervisors. However, requiring banks to issue such instruments, as FMA does, can impose costs on those institutions that would not voluntarily do so based solely on considerations of profit maximization. If the federal-funds market is capable of providing similar supervisory benefits, it makes sense to consider it as an alternative, given that most banks already participate in this market under their own free will.

Another potential supervisory aspect of discipline in fed funds—one that also relates to monetary policy—has to do with their substitutability for loans from the Discount Window. Although rates on Discount Window advances are not explicitly indexed to risk, banks have traditionally perceived that borrowing from the Fed both invites heavy regulatory scrutiny and sends a negative signal to the market. For these reasons, extended-credit lending has been virtually nonexistent for over a decade, and even adjustment credit has waned (see Furfine, 2001b, and Peristiani, 1998). Recently implemented policy changes (see Madigan and Nelson, 2002) have attempted to remove the stigma from Discount Window borrowing, under the logic that the Fed can act as a regular source of bank liquidity. Short-term loans from the "primary credit" facility are now priced as a spread above the target fed-funds rate (100 basis points as of 2004) and are granted to most banks without regard to the reason for the borrowing. The results here suggest that this "no questions asked" policy may cut off a potentially important source of supervisory information. Banks that are willing to pay this premium may be precisely those that are excluded from the fed-funds market because they are perceived as being too risky. Without additional information, supervisors are unable to distinguish between liquidity shocks that are random and relatively benign and those that reflect more serious problems with a bank's condition.

Finally, because of the fed-funds market's special role in the financial system and macroeconomy, its workings have broader implications for the determination of interest rates. If fed-funds rates respond to idiosyncratic or systemic levels of risk, the relationship between these rates and those of risk-free securities will vary over time with aggregate business conditions. Such spread variations have been noted empirically by Simon (1990) and Duffee (1996). In the extreme, these effects may interfere with the ability of the Federal Reserve to target macroeconomic factors using the effective fed-funds rate as an instrument.

The paper is organized as follows. The next section presents theoretical motivation for market-discipline tests in the interbank market. Section III describes the data and carries out these tests. Also, in section III.D, it motivates and tests for time variation in this discipline, as a result of regulatory changes. Finally, Section IV concludes.

II. Theoretical Considerations

Several authors have modeled the federal-funds market and banks' reserve-management decisions, but all work in this area has assumed that banks never default and thus abstracted from the possibility of risk pricing.[6] The primary consequence of introducing risk is that fed-funds prices include risk premia that differ from bank to bank. Raising the premium that some banks pay over the risk-free rate increases the range of the risk-free rate over which these banks will choose not to participate in the market. Thus, riskier banks are less likely to rely on fed funds as a source of liquidity.

More specifically, the theory generates two important and intuitive hypotheses. (For a formal derivation, see Appendix A.) First, the rate a bank pays on its federal funds should increase as the likelihood of default increases. Given a measure of default risk, this result suggests a straightforward empirical test. In fact, one can show that as default probabilities and risk-free rates go to zero, the slope in a regression of interest rates on these probabilities should approach unity from above. (For an approximately average bank with a failure probability of 1% facing a risk-free rate of 5%, the model suggests that the coefficient should be about 1.07.)

The second hypothesis is that banks that must pay these higher rates will be less likely to borrow in the fed-funds market. In particular, suppose that costly idiosyncratic liquidity shocks are randomly distributed with mean zero and that each bank i has an *ex ante* probability p_i of defaulting on its fed-funds purchases. Then the bank chooses fed-funds borrowing Q_i^* to set the expected marginal cost of a liquidity shock equal to the rate it must pay, which is determined by both p_i and the risk-free market rate of interest r_M. This implies a downward-sloping demand curve for federal funds with respect to r_M.

Banks with high liquidity will operate on the negative part of this demand curve in equilibrium—i.e., they will be sellers of fed funds. If risk is efficiently priced and banks are risk neutral, the expected return from interbank lending is simply r_M, and any positive default risk thus drives a wedge between the bank's cost of borrowing and expected return on lending in the fed-funds market. Therefore, as long as $p_i > 0$, any bank will choose to engage in neither sales nor purchases of fed funds over some non-trivial range of r_M. The higher the bank's probability of failure, the larger this wedge will be, and the greater the range of r_M over which the bank will choose not to participate.

Specifically, Appendix A derives the following relationship:

$$Q_i^* = \begin{cases} F^{-1}\left(1 - \dfrac{r_M + p_i}{r_d(1-p_i)}\right) - L_i & \text{if} \quad r_M < r_d(1-p_i)[1-F(L_i)] - p_i \\ 0 & \text{if} \quad r_d(1-p_i)[1-F(L_i)] - p_i \le r_M \le r_d[1-F(L_i)], \\ F^{-1}\left(1 - \dfrac{r_M}{r_d}\right) - L_i & \text{if} \quad r_M > r_d[1-F(L_i)] \end{cases} \qquad (1)$$

where L_i is bank i's stock of liquid assets prior to observing the liquidity shock, $F(.)$ is the cumulative distribution function of the liquidity shocks, and r_d is the cost per dollar of a liquidity shortfall (interpretable as the rate on Discount Window borrowing). Three examples of this relationship between Q_i^* and r_M are shown in Figure 2, for banks with different values of p_i and L_i. For the purposes of illustration, the figure corresponds to $L_1 = L_2 < L_3$ and $p_1 < p_2 < p_3$, and $F(.)$ is assumed to be normal.

FIGURE 1 ABOUT HERE

Equilibrium requires that the sum of the Q_i* over all banks in the economy equals zero. As long as the distributions of failure probabilities and liquid assets in the population of banks are well behaved, a unique market return r_M* exists that satisfies this condition. First-order stochastic increases in either of these distributions both cause r_M* to fall. In other words, raising the level of aggregate reserves or the level of aggregate risk reduces the risk-free interest rate. The negative response of r_M* to monetary injections is an example of the "liquidity effect" that has been studied by Rotemberg (1984) and Lucas (1990), among others. The negative response of r_M* to risk results from the decrease in demand brought about by higher risk premia. Note that, although the risk-free rate is decreasing in aggregate risk, risk premia increase by a greater amount, so the average rate actually paid on fed funds is increasing in aggregate risk. If, for example, the effective fed-funds rate is measured as the average of rates paid on fed funds purchased, it will rise with the average probability of failure.

Figure 2 illustrates these properties of equilibrium. In this situation, Bank 3, because of its high liquidity, does all of the fed-funds lending, and the amount that it lends, $-Q$, can be read off of its demand curve. The value of r_M adjusts to balance this quantity with the total demand for fed funds. Here, Bank 1 is the only bank that borrows. In equilibrium, Bank 2 finds its (risk-adjusted) cost of fed funds to be too high to make borrowing worthwhile but the market rate r_M^* too low to make lending worthwhile, so it does not participate. If Bank 1 did not exist, Bank 2 would borrow, although the amount exchanged would be less and r_M^* would be lower.

One unrealistic feature of this model is that it ignores the possibility of credit rationing in the Stiglitz-Weiss (1981) sense. In general, asymmetric information is a necessary condition for rationing to occur, whereas here all participants are assumed to be symmetrically informed about each bank's probability of default. Casual observation suggests that asymmetric information is a non-trivial problem in banking, and we have at least anecdotal evidence that credit rationing does indeed occur in the fed-funds market.[7] Informally, the presence of asymmetric information would affect the above results in three ways. First, given that the market cannot directly observe individual bank risk, we might expect it to rely on proxies that are observable at low cost. These might include idiosyncratic variables that are correlated with failure probability, such as bank size, and aggregate variables, such as the average level of risk in the economy. For this reason, an increase in the average risk of the population may impose greater borrowing costs on all banks, even those whose individual risk has not increased. Second, if information problems obscure a bank's true risk and the market relies instead on proxies, linear regression models of fed-funds prices on actual individual risk will yield coefficients that are less than what the model predicts (e.g., less than one for low-risk banks). Finally, unless banks are completely opaque, the extent of any credit rationing will itself vary positively with bank risk. Therefore, the finding that riskier banks borrow less will still hold, although it will no longer be entirely a consequence of the borrowing banks' own maximizing decisions. In Section III, I test all three of these propositions.

A related matter that is not explicitly captured by the theoretical model concerns bank size. Since at least Lucas et al. (1977), research has indicated that large banks tend to be net purchasers of federal funds, whereas smaller banks tend to be net sellers. As of 31 December 2002, banks with over $1 billion in total assets were net purchasers of fed funds, financing 6.12% of their assets through the interbank market. By contrast, banks with less than $1 billion in assets *sold* an average of 3.23% of their balance sheet as fed funds or reverse repurchase agreements. In part, this phenomenon results from differences in reserve requirements, but these differences are small for most banks and do not seem capable of accounting for the large discrepancies in interbank activity.[8] Moreover, when combined with the observation that small banks tend to pay several basis points more for fed funds than large banks (see Table III in the following section), it suggests that supply-side factors are at work.

Allen et al. (1989) conducted perhaps the most thorough formal empirical study documenting this phenomenon. They advanced three possible explanations for their result. First, smaller banks may have a preference for or comparative advantage in obtaining liquidity through sources other than the fed-funds market, such as core deposits. Second, small, community banks may exercise some local monopoly power over deposits and thus be able to generate them at lower cost than large banks. Finally—and most germane to the present study—smaller banks may tend to be riskier than large banks, and this risk may be manifested as either a higher cost of fed-funds borrowing or rationing in the fed-funds market. Moreover, even if two banks of different sizes have identical risk, greater information asymmetries may apply to the smaller one, resulting in a higher cost of borrowing (or more rationing) due to a lemons problem. In the presence of asymmetric information, lenders may also rely on bank size as a low-cost indicator of risk. Again, the empirical tests below, which explicitly include bank size as a regressor, are consistent with these marginally positive effects of size, holding risk levels constant.

III. Empirical Tests

The only other research to examine risk pricing in the federal-funds market explicitly was conducted by Furfine (2001a), who used Fedwire data during the first quarter of 1998, along with accounting information on interbank borrowers, to show that rates do tend to vary with borrower risk. His approach excluded transactions not conducted over Fedwire and, as he acknowledged, possibly misidentified some fed-funds brokers as borrowing banks. The dataset I use suffers from its own limitations (discussed below), but it covers a longer period and probably a larger cross section. The former is particularly important, because aggregate liquidity conditions and monetary-policy variables likely affect the pricing of fed funds differently at different stages of the business cycle. Moreover, studies of the discipline imposed on banks by other types of liability markets have demonstrated that the risk-elasticity of liabilities (i.e., the coefficients in a regression of yields on risk variables) can vary over time, depending on aggregate economic conditions and institutional considerations (e.g., Flannery and Sorescu, 1996, and Martinez Peria and Schmukler, 2001). One particularly nice feature of the longer dataset is that it allows one to test the effects of the early-1990s legislation that was designed to shift more of the burden of failure to uninsured creditors and thus should have enhanced market discipline.

The tests I run are in the spirit of the existing liability-market-discipline literature but are specifically tailored to address the theoretical model of the previous section. In particular, I use a two-stage procedure to identify linear demand and supply curves as functions of various bank-level and aggregate variables. Because each bank is assumed to face a perfectly elastic supply of interbank funds, the estimation of the supply curve (stage one) is simply a regression of individual interbank rates on bank risk and systemic factors. Estimation of the demand curve (stage two) uses the individual forecasted rates from the first stage, together with liquidity proxies and control variables, in a regression with interbank purchases as the dependent variable.

Formally, the system I estimate is

$$r_{it} = \beta_1 + \beta_2 p_{it} + \mathbf{x}_{it}^{'}\mathbf{B} + \varepsilon_{it} \tag{2}$$

$$Q_{it} = \gamma_1 + \gamma_2 \hat{r}_{it} + \mathbf{y}_{it}^{'}\mathbf{G} + \eta_{it}\,, \tag{3}$$

where r_{it} is the average rate paid on interbank borrowing by bank i in quarter t, Q_{it} is the average daily interbank borrowing by bank i in quarter t scaled by total assets, p_{it} is a measure of individual bank-failure probability, x_{it} and y_{it} are vectors of liquidity proxies and other idiosyncratic and systemic control variables, and ε_{it} and η_{it} are least-squares error terms with the usual properties. $\hat{r}_{it}$ is the forecast of the individual interbank rate generated by the estimation of the first equation. The estimation of equation (2) can thus be viewed as an instrumenting procedure for r. This approach has the advantage of allowing one to include in the stage-two estimation even those banks that did not have any purchases and that thus report no explicit fed-funds expense (although, when the same sample of banks is used for both equations and r is used directly in equation (3), the results are similar to those I report below).[9]

I also estimate a modified version of equation (3):

$$Q_{it} = \gamma_1 + \gamma_2 \hat{r}_{it} + \gamma_3 p_{it} + \mathbf{y}_{it}^{'}\mathbf{G} + \eta_{it}\,. \tag{4}$$

Including p_{it} in this specification captures any marginal impact of bank risk on interbank reliance beyond the effects operating through prices. In particular, if the market imposes discipline by quantity rationing, the coefficient on p_{it} in equation (4) should be negative and significant.

The independent variable representing default risk p_{it} is the bank-failure probability generated by the Federal Reserve's System to Estimate Examination Ratings (SEER) model.[10] SEER is a probit regression of bank-failure events on eleven independent variables that capture various aspects of bank risk. These variables, together with the signs of their coefficients in the probit regression, are listed in Table II, and the time series of average SEER-estimated failure probabilities is depicted in Figure 2. Technically, a bank's SEER score is interpretable as the probability that it will fail over the coming four quarters.[11] More informally, it can be thought of as an index for a bank's overall risk position. SEER performs well relative to other "early-warning" models of bank risk (see Gilbert et al., 2002) and is verified annually by economists at the Board of Governors. Its parameters and forecasts are confidential.

TABLE II ABOUT HERE

FIGURE 2 ABOUT HERE

The variables included in the x vector fall generally into two categories, inspired by the theoretical model. The first is a set of proxies for market liquidity. In general, tighter market conditions—i.e., lower aggregate liquidity—should raise the required rate of return on fed funds. The liquidity variables I include are the ratio of the monetary base to required reserves, aggregate loan growth, and the three-month Treasury bill yield. The T-bill yield serves to indicate the general level of interest rates (on the short end of the yield curve), and I thus expect its coefficient to be close to unity. An alternative specification uses the discount rate instead. The second category of variables captures the effects of imperfect information. When the condition of a borrowing bank is difficult to assess, sellers of fed funds may rely upon more easily observable proxies for individual bank risk, such as bank size, or on what they know about general market conditions, such as market credit-risk spreads. Accordingly, I include the log of real total assets of each bank, as well as the spread of Baa-rated corporate bonds over ten-year Treasury notes. The latter have been shown to reflect systematic risk in the financial sector by Fama and French (1993) and Elton et al. (2000).

The control variables in the demand equation—the components of the y vector—proxy for individual liquidity needs (as distinct from the *market* liquidity variables that enter into the supply equation). Specifically, for each bank, I include the discount rate, non-pledged securities holdings as a percentage of assets, annualized quarterly loan and core-deposit growth, the available line of credit with the Federal Home Loan Bank as a percentage of assets, and the log of real assets. The loan- and deposit-growth variables are intended to capture (with opposite signs) a bank's demand for short-term funding; non-pledged securities, the Discount Window, and FHLB access represent alternative, non-interbank sources of funding supply.[12]

Table III lists summary statistics for the regression variables. Various technical matters and restrictions concerning the computation of these variables are described in the following sub-section. In all, the sample contains an average of 31 quarterly observations on each of 12,275 unique commercial banks.

TABLE III ABOUT HERE

A. Data Issues

The time-series data used in this study are available from the FRED database on the Federal Reserve Bank of St. Louis's website. The bank-level data are taken from the Consolidated Reports of Condition and Income (Call Reports) filed quarterly by all commercial banks with their primary regulators. Although the bulk of the balance-sheet data included in the Call Reports is reported as of the end of each quarter, several series—including interbank borrowing—are also reported as quarterly averages of daily values (on Schedule RC-K). Whenever possible, these quarterly averages of balance-sheet variables are used as regressors. In a few instances, however, variables are not reported as quarterly averages, and in these cases I use the average of the end-of-quarter data from the contemporaneous quarter and the quarter immediately preceding. In particular, this calculation is necessary for the levels of pledged securities, FHLB advances, and the SEER values.

The quarterly averages, together with income-statement variables, allow for the computation of average quarterly interest rates paid by each bank on various liabilities. The dependent variable in the stage-one estimation (equation (2)) is the quarterly average rate paid on interbank borrowing for each bank, thus computed. The time series of the average of these rates is shown in Figure 3, and its distributional statistics are reported in Table IV. The effective federal-funds rate reported by the Federal Reserve is given for comparison. In general, the effective rate is close to the average of the rates computed from the Call Report data, although the latter exhibit substantial cross-sectional variation.[13] As the bottom two rows of the table show, larger banks (those with total assets of over $1 billion in 1996 dollars) pay somewhat lower rates on average and exhibit somewhat less variability in these rates. However, even among these institutions, the within-quarter standard deviation is 41 basis points higher than that of the effective rate—i.e., considerable heterogeneity remains.

The use of accounting data in studying market phenomena such as risk pricing is inevitably complicated by certain difficulties. Often, the most intractable of these is adjusting for the term structure of liabilities using imperfect data on remaining maturities. Researchers such as James (1990) and Hall et al. (2002) have employed complicated but still imperfect techniques to minimize the resulting measurement error. Fortunately, in the case of federal funds, maturities are quite uniform and extremely short, so that measurement-error problems of this type are virtually nonexistent. Figure 3 is evidence of this, as it shows that the accounting-based measure tracks the contemporaneous market data closely.

An additional complication is that accounting data can be somewhat noisy, particularly when they involve relatively small quantities. For example, computing the rates paid on interbank purchases in the manner described above results in values in excess of 100% for some banks and less than 0% for others. Some restrictions on admissible observations are thus necessary to screen out data-entry errors and other clearly impossible values. The advantages of this screening must, of course, be weighed against the risk of eliminating potentially informative heterogeneity in the data. I adopt a conservative approach, removing from the sample all banks with computed rates that lie either below zero or outside a 400-basis-point band around the contemporaneous effective fed-funds rate.[14] This restriction does away with less than 8% of the available observations, but it considerably reduces the variance of the sample. I also impose various other screens (e.g., loans and core deposits cannot change by more than a factor of two in any given quarter) to eliminate data errors. Banks involved in mergers within the previous two years are also excluded.

Another issue arises in the treatment of security-repurchase agreements ("repos"). Because they are essentially short-term interbank loans, repos are close substitutes for fed funds. However, repos are collateralized with Treasury securities, effectively eliminating their default risk.[15] For much of the sample period, the Call Report lumps fed funds and repos into a single balance-sheet category, and this is the item used to compute the variables in the regressions. Even during the period when the two are reported separately on the balance sheet (1988 – 1996), the interest expense is still combined, making individual rates paid on each item impossible to compute. Fortunately, repos are generally much less prevalent than fed funds. As of December 1996, the last date for which hard data are available, fed funds constituted 75% of overnight lending, with repos making up just 25%. Moreover, to the extent that the data are contaminated with repos, the safety of these instruments should bias the risk-sensitivity estimates toward zero, working *against* a finding of market discipline. Indeed, we might expect that those banks that are most likely to face discipline in the fed-funds market have the greatest incentives to turn to repos as an alternative source of funding. Repurchase activity is also correlated with bank size, so that some of this effect may be accounted for by the inclusion of total assets in the regressions. Some tests that use the 1988-96 data to account explicitly for repurchase reliance are reported in Section B3 of the appendix. In general, they indicate that the presence of repurchase agreements in the data has little material effect on the empirical results.

B. Stage One: Supply-Curve Estimation

Table V reports the results of the equation (2) regressions. The first column contains the specification that I will use as the baseline. Every parameter is statistically significant at the 1% level and has the anticipated sign. As expected, the coefficient on the Treasury yield is close to unity, indicating that the accounting data track the time series of short-term interest rates closely. Lower systemic levels of the monetary base, relative to required reserves, and higher systemic loan growth are associated with higher interbank premia, which is consistent with liquidity-based supply stories.

TABLE V ABOUT HERE

The positive and statistically significant coefficient on failure probability indicates that riskier banks are indeed being charged more for fed funds. Tests designed to determine the specific types of risk that the market is responding to (reported in Section B4 of the appendix) show that credit and liquidity risk are the primary factors driving this result. However, the magnitude of the failure-probability coefficient is smaller than we might expect: on average, a ten-percentage-point increase in failure probability leads to a fed-funds rate that is just 3 basis points higher. This result is quite robust to different sample restrictions and specifications, as can be seen, for example, in the other columns of the table, which report the regression results when the discount rate is used instead of the Treasury rate, when all of the control variables except the level of interest rates are omitted, and when the level of interest rates itself is omitted.

SEER failure probabilities greater than 10% are rare, so we must conclude that the economic significance of risk pricing was small for most banks over the sample period. In other words, the response of the fed-funds market to bank risk was not likely to impose enough of a drain on profitability to compel management to restrain its risk appetite. In the terminology of Bliss and

Flannery (2001), the market exhibits *monitoring* but not *influence*. Although bank supervisors may be able to rely on the fed-funds market to provide statistically significant signals about bank risk, the effectiveness of fed-funds sellers themselves in imposing true discipline on other banks appears to be limited.

We should keep in mind that various characteristics of the data are likely to bias the risk coefficient toward zero. In particular, the noise permitted by the rather broad sample restrictions, the inclusion of repurchase agreements in the fed-funds data, and the possible recovery of some principle in the event of borrower failure mean that the result is probably understated. That the coefficient is statistically significant despite these contaminating factors is evidence of the strength of the underlying relationship. Its magnitude can be viewed as a lower bound on the price effects of risk. However, as mentioned in Section II, competitive market discipline implies a coefficient of approximately one on default probability for low-risk banks and substantially greater than one for high-risk banks. In order to claim that risk pricing in this market is efficient, one would thus have to argue that the data problems described above are sufficient to bias the coefficient downward by three orders of magnitude.

Alternatively, a possible economic explanation for the low coefficient is that bank assets are relatively opaque, and thus the intense monitoring that would be required to assess their risk accurately is costly. On the other hand, the two remaining variables—log of assets and the bond-market credit premium—are both easily observable potential proxies for individual bank risk. The statistical and economic significance of each of these variables in the regression is considerably larger than that of failure probability, suggesting that asymmetric-information problems indeed cause banks to rely what they know about market conditions when pricing short-term loans to other banks. In particular, note that, even controlling for their lower average risk levels, larger banks pay significantly less for fed funds: on average, doubling a bank's size allows it to purchase fed funds at a rate that is eleven basis points lower.

C. Stage Two: Demand-Curve Estimation

I now turn to the estimation of the demand curves given by equation (3). The results of these regressions are reported in Table VI. The dependent variable in this model is interbank borrowing as a percentage of total assets, and the stage-one regressions are used to estimate an implicit interbank rate for each bank. Again, I take the model in the first column as the baseline specification, but the results of various alternatives are consistent. In particular, the second column, which omits the control variables, demonstrates that the inclusion of the controls does not affect the central result of a downward slope with respect to the rate paid.

TABLE VI ABOUT HERE

The regressions show that interbank borrowing tends to decrease as the rate that would have to be paid on it rises. A 100-basis-point increase in the individual rate leads to a 10-basis-point decrease in borrowing. As reported in Table 3, average interbank reliance is 1.58% of total assets, and the median value is just 0.05%, so these coefficient magnitudes would seem to be significant economically. (For example, a 50-basis-point increase in the median bank's fed-funds rate would be enough to drive it from positive borrowing to zero.)

The coefficients on the control variables are also in agreement with theoretical intuition. Increases in non-pledged securities and core deposits and decreases in loan growth significantly lower interbank borrowing, as we expect, given the effects of these variables on a bank's liquidity position. Access to the FHLB also decreases gross interbank purchases, as one would predict. Consistent with previous findings, a higher discount rate tends to increase borrowing in the interbank market. Finally, an increase in bank size is associated greater borrowing. This reflects differences in reserve requirements and, as Allen et al. (1989) describe, differences across size in risk aversion and monopoly power in local deposit markets.

The final column in the table reports the results of equation (4), which adds failure probability as a regressor. Again, this variable is intended to capture any effects of bank risk on fed funds borrowing, beyond those working through the price channel. Specifically, the negative and significant value is consistent with non-price rationing. Although the magnitude of this coefficient is not particularly large, it would seem to be at least as economically significant as the risk coefficient in the stage-one regressions. For example, a ten-percentage-point increase in failure probability reduces interbank reliance by 14 basis points (about 9% of the average reliance). Because such rationing is only likely to occur in the presence of asymmetric information, this result strengthens the implication of the pricing equations that information flows between banks are less than perfect.

D. Testing for Changes in Market Discipline

Much of the heterogeneity in the sample comes from the banking crisis of the late 1980s and early 1990s. Yet federal legislation since that time has placed fed-funds sellers at greater risk than ever by increasing the likelihood that they will suffer losses if a borrowing institution fails, thus increasing the incentives for monitoring and discipline. In the first such move, the FDIC Improvement Act (FDICIA) of 1991 instituted least-cost failure resolution. Prior to this legislation, the FDIC had resolved most bank failures through purchase and assumption, under which method even uninsured liability holders were often protected. The numbers suggest that the FDIC is indeed serious about least-cost resolution: as shown in Benston and Kaufman (1998), uninsured depositors were protected in 81% of the bank failures in the six years preceding FDICIA; in the six years following, the figure was just 37%. FDICIA also included provisions intended to retreat from the Too Big to Fail policy, which may have previously led lenders of fed funds to large banks to believe that their loans were insured *de facto*.[16]

Two other regulatory changes hit the fed-funds market in the early 1990s. Federal Reserve Regulation F, implemented in 1994, imposed limits on interbank lending to undercapitalized institutions. In practice, this regulation restricts the supply of fed funds to weak banks and raises the expected costs to fed-funds sellers of lending to such banks. Finally, and perhaps most importantly, the National Depositor Preference Act (NDPA) of 1993 rearranged the failure-resolution hierarchy, subordinating fed funds to almost all other bank liabilities, thus increasing the expected loss to fed-funds sellers in the event of bankruptcy. (See Marino and Bennett (1999) for details on NDPA.) By shifting more of the costs of failure to sellers of fed funds, all three of these innovations in the regulatory environment should have increased the incentives for monitoring and discipline in the interbank market.

To get a sense for time variation in the parameters that may be masked when the data are pooled, I re-run models (2) and (4) year-by-year. The coefficients on individual failure probability in each equation are plotted in Figure 4. The figure demonstrates a marked rise in the magnitudes of the coefficients in both equations in the second half of the sample period. As discussed above, this finding is consistent with the theoretically predicted effects of FDICIA, NDPA, and Regulation F, which were implemented during the years 1992 through 1994. A Chow test for a structural break in the first quarter of 1995 rejects equality of the coefficients at the 1% level in both equations—in both cases, the coefficient on risk more than doubles between the two periods. Results using other sample-split dates in the 1992 – 1995 period are similar. These findings indicate that market discipline—both through pricing and quantity rationing—increased in the fed-funds market during the late 1990s.

FIGURE 4 ABOUT HERE

IV. Conclusions

The theory presented in Section II implies that individual and aggregate bank risk could play a role in banks' pricing of and reliance on federal funds. The extent of this role in reality is an empirical question, one that I have attempted to address in Section III. The results there indicate that idiosyncratic bank risk is a factor in the rates paid on fed funds and that reliance on purchases of fed funds tends to decrease as the cost of such purchases rises. Although the economic importance of idiosyncratic risk is small relative to that of other variables, there is also evidence that, in the wake of the early-1990s legislation designed to shift more of the burden of bank failure to uninsured creditors, the monitoring and pricing of individual bank risk increased substantially. Some discipline also seems to take the form of non-price rationing, and the incidence of this behavior has also increased in recent years. In making these price and quantity decisions, lending banks appear to rely on borrower asset size and aggregate levels of financial risk as guides. Together, the results are consistent with significant market discipline in the fed-funds market, although they also suggest the presence of information problems.

The finding that risky banks can be priced or rationed out of the fed funds market establishes a link between risk and liquidity. As long as banks have other options for short-term funding, such as Federal Home Loan Bank advances, pledgable or tradable securities, and brokered deposits, limited access to the fed-funds market should impose little difficulty. If, however, these sources should dry up, it is possible that idiosyncratic liquidity shocks to risky but otherwise solvent banks could precipitate failure. Because fed-funds pricing appears to reflect systemic levels of risk even more than individual levels, this scenario is more likely to occur in an environment with higher aggregate levels of risk. Furthermore, although the pricing-equation coefficients on risk are positive and significant, they are substantially less than the values that would indicate actuarially fair risk-pricing. Consequently, it would seem that lenders of fed funds are not adequately compensated for the risks they bear, and idiosyncratic failure events could thus spread problems throughout the system via a contagion effect.

On the other hand, the statistical strength of the idiosyncratic risk coefficients opens the possibility that fed-funds data may be a useful supervisory tool. The low magnitude of these estimates makes it unlikely that the government could delegate its risk-disciplining role to the fed-funds market, but it may be able to derive a serviceable signal from this market for offsite surveillance purposes. Although beyond the scope of this paper, one could, for example, estimate a model along the lines of SEER or the rating-downgrade model of Gilbert et al. (2002) including idiosyncratic rates paid and reliance on fed funds as explanatory variables.[17]

In the absence of such a model, the government still has access to an institutional device that could essentially serve the same purpose, namely the Discount Window. Prior to the recent reforms, supervisors viewed extended-credit Discount Window borrowing as a negative signal about bank risk and subjected borrowers to more intense safety-and-soundness examinations. Based on the theory and evidence I have presented, this policy was rational: riskier banks are indeed more likely to be excluded from the fed-funds market and thus to turn to the Discount Window as a last resort. The new Discount Window regime, with its "no questions asked" rule, constrains supervisors to ignore a potentially useful signal. As Flannery (1996) has argued:

> The necessary condition for government intervention in credit markets is not that private markets are doing a poor job, but that the government can do better. Unless the government possesses superior information about individual banks' solvency, it is difficult to defend the proposition that a government LLR [lender of last resort] should displace private credit decisions and assessments during a crisis.

The evidence I have presented indicates that the "private credit decisions and assessments" are far from perfect. Yet, as long as the Fed is statutorily prohibited from gathering information about borrowing banks, it is not clear that it can improve social welfare through routine Discount Window lending. Indeed, the adverse-selection problem suggests the opposite.

Finally, with regard to interest-rate determination, the results presented here imply a time-varying spread between fed-funds rates and risk-free rates. The effective federal-funds rate targeted by the Federal Reserve is derived from a small sample of rates on brokered interbank transactions, so the extent to which it will embed this risk premium is unclear. However, Simon (1990) and Duffee (1996) have noted time variation in the spread of the effective fed-funds rate over short-term Treasuries, with Simon directly implicating banking-system risk in this phenomenon. In addition, Sarno and Thornton (2003) have suggested that it is the Treasury market, rather than the fed-funds market, that truly “anchors” interest rates. Indeed, if monetary policy’s first-order effect is to move short-term riskless rates of interest, the focus on federal funds, which are subject to risk premia, may be misplaced.

Appendix A: A Model of the Fed-Funds Market

This appendix presents a theoretical model of the federal funds market that yields equation (1) and Figure 1, as well as the central hypotheses addressed with the empirical tests. The timing of the model is roughly similar to that used in many previous studies. Each bank i begins the day with some stock of liquid assets L_i, which is most usefully thought of as excess reserves but may also include other sources of liquidity, such as lines of credit with the FHLB. It targets its end-of-day excess-reserve position R_i using fed-funds purchases, but, after the decision about the quantity of purchases is made, the bank is subject to an idiosyncratic stochastic shock that is out of its control. That is,

$$R_i = L_i + Q_i + e_i ,$$

where Q_i is the bank's purchases of fed funds and e_i is a mean-zero random variable with a symmetric and continuous probability density function $f(e_i)$. For now, I restrict attention to the hypothetical case in which a bank is only permitted to purchase fed funds, not to sell them, i.e., $Q_i \geq 0$. After the shock e_i is realized (but before any borrowed funds are repaid) the bank fails with some probability p_i. In this case, all principal and interest that the bank owes are lost. This probability can be thought of as aggregating the credit, interest-rate, and other risks of all the bank's assets and is assumed to be out of management's control at the daily frequency considered here. p_i is also assumed to be independent of L_i and e_i, so that liquidity shocks do not cause failure in this model, which is consistent with the existence of a lender of last resort.[18]

Assume that any excess reserves at the end of the day earn zero return.[19] On the other hand, reserve deficiencies must be made up by borrowing from the Discount Window at a rate of r_d (which may also be thought of as including any penalty fees and costs of added regulatory scrutiny).[20] The market for fed funds is assumed to be competitive, and all participants are assumed to be risk-neutral, so that the rate paid by each borrowing bank is actuarially fair. That is, the expected return to the lender is equal to the (risk-free) opportunity cost of lending r_M. Thus, the market will set the rate r_i on bank i's purchases of fed funds such that

$$[p_i \times 0] + [(1 - p_i)(1 + r_i)] = 1 + r_M \ .$$

Solving for r_i gives

$$r_i = \frac{1 + r_M}{1 - p_i} - 1 \, . \tag{A1}$$

Thus,

$$\frac{\partial r_i}{\partial p_i} > 0$$

This simple observation—that rates paid on fed funds are higher for banks in greater danger of failure—is one of the central hypotheses tested in Section III, and it is not rejected. However, we should also note that, for $p_i > 0$ and $r_M > 0$, equation (A1) yields the stronger condition

$$\frac{\partial r_i}{\partial p_i} > 1 \, ,$$

and this hypothesis *is* rejected by the data. As reported in the text, most values of p_i are close to zero in reality. For low values of p_i and r_M, the theory predicts this derivative should be close to, but not less than, unity.

The profit from fed-funds operations is

$$\pi_i = \begin{cases} -r_i Q_i & \text{if} \quad e_i > -(Q_i + L_i) \\ -r_d(L_i + Q_i + e_i) - r_i Q_i & \text{if} \quad e_i \leq -(Q_i + L_i) \end{cases} .$$

Following previous authors, I assume that the daily fed-funds decision is independent of all other aspects of the bank, so that the profit-maximization problem in fed funds can be considered independently of the bank's other characteristics. Thus, expected profits are given by

$$E[\pi_i] = r_d \int_{-\infty}^{-Q_i - L_i} (L_i + Q_i + e_i) f(e_i) de_i - r_i Q_i \, .$$

The first-order condition for profit maximization when the non-negativity constraint on Q_i does not bind is

$$r_d F\left(-Q_i^* - L_i\right) = r_i \,,$$

where Q_i* is the maximizing value of fed funds purchased, and $F(.)$ is the cumulative distribution function associated with $f(.)$. Rearranging,

$$Q_i^* = F^{-1}\left(1 - \frac{r_i}{r_d}\right) - L_i \,.$$

This inverse-CDF demand curve for fed funds is similar to the result derived by Poole (1968). Because $F(.)$ is a monotonically increasing function, its inverse $F^{-1}(.)$ is well defined for $r_i < r_d$ with a positive first derivative. Therefore,

$$\frac{\partial Q_i^*}{\partial r_i} < 0 \text{, and } \frac{\partial Q_i^*}{\partial r_d} > 0 \,. \tag{A2}$$

The first inequality in (A2) represents the other major hypothesis that is tested in Section III, namely, that a bank's demand for fed funds is negatively related to the individually risk-priced rate that it must pay on them. Moreover, because f is symmetric around zero, we have

$$Q_i^* = \begin{cases} F^{-1}\left(1 - \dfrac{r_M + p_i}{r_d\left(1 - p_i\right)}\right) - L_i & if \quad p_i < \dfrac{r_d\left[1 - F\left(L_i\right)\right] - r_M}{r_d\left[1 - F\left(L_i\right)\right] + 1} \\ 0 & otherwise \end{cases} .$$

Thus, all else equal, riskier banks are more likely not to borrow in the fed-funds market, and, if they do borrow, the amount of the borrowing will be less than for a comparable safer bank. Also note that the model also predicts an inverse relationship between the spread of r_M over the discount rate and the reliance on fed funds, a phenomenon that has been repeatedly documented empirically (see Clouse, 1994).

Extending the model to a general-equilibrium setting and permitting fed-funds sales allows one to determine the risk-free rate r_M—the central goal of most previous models of the federal-funds market. Consider a continuum of risk-neutral banks indexed by $i \in [0, 1]$ that are now allowed to have negative fed-funds borrowing. Let e_i and e_j be independently distributed for $i \neq j$ and redefine r_i as

$$r_i \equiv \begin{cases} \dfrac{1+r_M}{1-p_i} - 1 & if \quad Q_i > 0 \\ r_M & if \quad Q_i < 0 \end{cases}.$$

For banks with positive borrowing, this situation is the same as the one described above. A bank that sells fed funds, on the other hand, earns the market rate of return r_M. This rate is net of any losses but also includes the average risk premium, and these effects exactly cancel each other as the number of banks goes to infinity. r_M therefore retains its interpretation as the risk-free rate. Let failure probabilities and liquidity be distributed throughout the population according to continuous density functions $g(p_i)$ and $h(L_i)$. Note that the mean of h need not be zero, reflecting the possibility of excess reserves in the system.

Each bank's demand function for fed funds (negative values of which now indicate sales) is given by:

$$Q_i^* = \begin{cases} F^{-1}\left(1 - \dfrac{r_M + p_i}{r_d(1-p_i)}\right) - L_i & if \quad r_M < r_d(1-p_i)[1-F(L_i)] - p_i \\ 0 & if \quad r_d(1-p_i)[1-F(L_i)] - p_i \le r_M \le r_d[1-F(L_i)] \\ F^{-1}\left(1 - \dfrac{r_M}{r_d}\right) - L_i & if \quad r_M > r_d[1-F(L_i)] \end{cases}.$$

This is equation (1) in the text. General equilibrium requires that

$$\int_0^1 Q_i^* di = 0 . \tag{A3}$$

Given reasonable conditions on g and h, a unique market return r_M* exists that satisfies equation (A3). The determination of return r_M* is illustrated graphically in Figure 1.

Appendix B: Additional Robustness Checks

This appendix presents the results of various alternative sample restrictions and regression specifications mentioned as robustness checks. In general, the outcomes of these tests are consistent with those reported in the body of the text.

B1. Alternative Demand Curves

Because the gross-fed-funds-purchased variable is censored at zero, the appropriate specification for the demand equation is a Tobit model. Alternatively, one can use fed funds purchases net of sales as the dependent variable, permitting negative values to occur. The results of both of these models, both including and excluding the control variables, are presented in Table B-I. Overall, the coefficient signs, significance patterns, and magnitudes agree with those reported in Table VI. Most importantly, the coefficient on the estimated individual fed-funds rate is negative and significant.

TABLE B-I ABOUT HERE

B2. Alternative Restrictions on Admissible Observations

In estimating the pricing equations in Section III, I impose certain restrictions on the data in order to reduce the noise of the sample. The most arbitrary of these restrictions is the selection of the acceptable range for the individual fed-funds rates computed from the accounting data. As described in the "Data Issues" sub-section, some computed values are clearly erroneous, but there is no obvious criterion for determining exactly what a reasonable range should be. Fortunately, the results are not particularly sensitive to this choice. In the regressions reported in Section III, I use a 400-basis-point band around the effective fed-funds rate, a cutoff that likely errs on the side of including more noise, given that, anecdotally, deviations of individual fed-funds rates of 400 basis points from the effective rate appear to be rare, if they occur at all. Table A-II presents the results of the baseline pricing model (equation (2)) for different values of this admissible range, including the case in which no restriction is imposed (i.e., the band is set to infinity). Except in the completely unrestricted case (which is obviously not ideal), the coefficient magnitude and significance patterns are fairly consistent. In particular, the coefficient on failure probability is always positive and significant but economically small.

TABLE B-II ABOUT HERE

B3. Testing the Effects of Repurchase Agreements

Throughout most of the sample period, the Call Reports included fed-funds borrowings together with repurchase agreements in a single balance-sheet item. Because repos are collateralized and effectively carry zero default risk, their presence almost certainly biases the risk coefficients toward zero. Even worse, there may be a systematic component to this bias: banks with higher risk may be precisely the ones that are more likely to rely on repos, potentially causing their total interest expense on interbank borrowing to be lower than that of a safer bank. The statistical strength and robustness of the positive coefficient on risk in estimations of equation (2) and (4) suggest that this effect, if it exists, is not sufficient to obscure the presence of risk sensitivity entirely. However, the low economic significance of the results may be driven by substitution into repos by the riskiest banks.

Between the years 1988 and 1996, the Call Reports included certain additional information that can provide some evidence on the role of repos. In particular, during this time, the Call Reports broke out fed funds purchased and repurchase agreements into separate categories in the end-of-quarter data. The quarterly average data continued to report them as a single item, and the income statements continued to conflate their interest expense. Nevertheless, these data allow us to examine the characteristics of banks that relied heavily on repos versus those that relied heavily on fed funds during this period.

Some statistics pertaining to this issue are presented in Table B-III. Here, I extract two extreme sub-samples of banks: those that relied on fed funds for more than 90% of their interbank funding, and those that relied on repos for more than 90% of their interbank funding. (Other cutoffs between 75% and 100% yield similar values.) Over half of all banks allowed by the other sample restrictions fall into one of these two groups, suggesting that most banks do have a strong preference for one type of funding or the other. Whatever the source of this preference, however, it does not seem to be related to the main variables in the model: in terms of risk, cost of funds, and participation in the interbank market, the two groups are nearly identical. There is, however, a large difference in their average size, perhaps suggesting differential market access.

TABLE B-III ABOUT HERE

Table B-IV reports the results of the baseline demand model, equation (2), for both the fed-funds and repo banks with the 90% cutoff. Predictably, the coefficient on failure probability is not significant for the banks that relied primarily on repos. However, the presence of repos in the data does not appear to be responsible for the low economic significance of the results on the full sample. Even among banks that rely on fed funds for 90% of their interbank borrowing, the coefficient on failure probability is just 0.004.

TABLE B-IV ABOUT HERE

B4. Pricing Using Alternative Risk Measures

Although the SEER model is intended to capture a range of different types of risk and condense them into an index for overall bank health, it is, of course, not the only way of measuring the risk of an institution. For example, government supervisors summarize their perception of a bank's quality in the CAMELS scores they assign. In this subsection, I report the results of the baseline pricing regression using this alternative measure of risk. I also run this regression on the individual components of the SEER model and the categorical CAMELS scores. In addition to enabling the model to fit the data more closely, this approach allows one to determine whether the fed-funds market is concerned with any specific *types* of risk.

"CAMELS" is an acronym standing for capital adequacy ("C"), asset quality ("A"), management ("M"), earnings ("E"), liquidity risk ("L"), and market sensitivity ("S"). During each onsite examination, supervisors rate a bank in each of these categories on a scale from 1 (best) to 5 (worst). They also assign a composite score that reflects the overall risk of the institution. Technically, the composite scores prior to 1997 were "CAMEL" scores, because the S rating had not yet been adopted, but their interpretation as representing the overall risk of the bank has remained the same. All CAMELS data are kept confidential by the supervisory agencies.

The second column of Table B-V uses the CAMELS composite score as the risk metric.[21] There are fewer observations for this regression, because CAMELS scores are not assigned to every bank in every quarter. The results are consistent with those obtained when SEER is used: the coefficient is positive and significant at the one-percent level, although its economic significance appears to be small. On average, an increase of one point in the composite CAMELS rating is associated with a four-basis-point increase in the cost of fed funds. The riskiest banks of all, those with scores of 5, pay 16 basis points more than the safest banks, those with scores of 1. This finding is of the same order of magnitude as that obtained using SEER, which predicts that banks with 100% probabilities of failure will pay 30 basis points more than those with 0% probabilities of failure.

The decompositions, reported in the third through fifth columns, show that the fed-funds market primarily prices credit and liquidity risk. The three SEER variables relating to loan quality—loans 30 days past due, loans 90 days past due, and nonaccruing loans—all enter with significantly positive coefficients, and the coefficient on residential-real-estate loans, which are regarded as particularly safe, is negative and significant. Additionally, the coefficient on the "A" component of the CAMELS score, indicating asset quality, is positive and significant. The two SEER variables that proxy for liquidity risk, securities and jumbo CDs, are also significant with the anticipated signs, as is the CAMELS "L" rating. Finally, the "S" component of CAMELS, which primarily reflects interest-rate risk, is positive and significant. On the other hand, a few regressors are significant with signs that are the opposite of what theory predicts—commercial and industrial loans, other real estate owned, and the earnings variables. The counterintuitive signs on these variables may reflect, in part, the fed-funds market's conflicting concern for liquidity versus overall safety and soundness. Perhaps most surprisingly, the market appears to pay little attention to bank capital, a variable that is typically thought to play a large role in bank failures. Both the SEER proxy (total net worth) and the CAMELS component ("C") for capital are statistically insignificant, although their coefficients have the anticipated negative sign.

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Table I

Comparison of Interbank Borrowing at Failing and Non-Failing Banks

	Interbank borrowing / total assets			*Individual interbank rate paid less 3-month T-Bill rate*		
Quarters prior to failure	Failed banks (std. dev)	Non-failed banks (std. dev)	Difference (t-statistic)	Failed banks (std. dev)	Non-failed banks (std. dev)	Difference (t-statistic)
1 Qtr	0.87% (3.30%)	1.30% (3.95%)	-0.43%*** (-4.40)	0.70% (1.45%)	0.15% (1.38%)	0.55%*** (6.44)
2 Qtrs	1.03% (3.61%)	1.29% (3.92%)	-0.26%*** (-2.37)	0.58% (1.48%)	0.16% (1.38%)	0.42%*** (5.17)
4 Qtrs	1.01% (3.35%)	1.25% (3.87%)	-0.25%*** (-2.46)	0.74% (1.41%)	0.18% (1.39%)	0.57%*** (7.37)
8 Qtrs	1.22% (3.24%)	1.20% (3.75%)	0.02% (0.21)	0.79% (1.43%)	0.18% (1.40%)	0.61%*** (7.97)

Notes: This table shows the patterns of reliance on and pricing of interbank borrowing at failing commercial banks between 1987 and 2002, compared to contemporaneous banks that did not fail. The "failed banks" sample includes 1,124 bank failures, but—due to various sample restrictions (see Section III of text) and because many failing banks did not borrow in the interbank market—only 348 of these failures could be used in the premium comparison in the right-hand columns. The "non-failed banks" sample includes all institutions that did not fail in each quarter, about 691,000 observations in total. The small quarterly changes in the averages for this sample reflect the systematic time trends in the data. Statistical significance at the 1% level for the one-tailed difference-of-means tests is denoted by ***. By four quarters prior to failure, failing banks both pay significantly more for interbank loans than their peers and rely significantly less on such loans.

Table II
Variables in the SEER Model

	Variable	Effect on failure probability	Sample Mean	Sample Std. Dev.
SEER failure probability			0.85%	5.76%
Asset Quality	Loans 30-90 days past due	+	0.89%	0.80%
	Loans past due 90+ days	+	0.22%	0.41%
	Nonaccrual loans	+	0.50%	0.78%
	Other real estate owned	+	0.25%	0.68%
	Commercial & industrial loans	+	11.11%	7.41%
	Residential real estate loans	–	16.99%	10.45%
Capital	Tangible net worth	–	8.71%	2.40%
Earnings	Net income (ROA)	–	1.11%	0.73%
Liquidity	Investment securities	–	28.89%	13.32%
	Large time deposits	+	9.47%	6.30%
	Natural log of total assets	–	11.78	1.19

Notes: This table, adapted in part from Cole et al. (1995), displays the explanatory variables included in the Federal Reserve's System to Estimate Examination Ratings (SEER), a probit regression used to compute probabilities of bank failure. These probabilities are used as the primary metric of default risk in the empirical tests of this paper. "+" indicates that higher levels of the variable lead to higher failure probabilities; "–" indicates the opposite. All variables (except the log of assets) are scaled by total assets. Summary statistics are computed for the sample used in the baseline estimation of equation (2) (164,708 observations).

Table III

Summary Statistics for Regression Variables

		Mean	Median	Std. Dev.	Min.	Max.
r	Individual interbank rate	5.22%	5.17%	2.01%	0.06%	13.71%
Q	Interbank borrowing / assets	1.58%	0.05%	3.72%	0.00%	100.00%
p	SEER failure probability	0.85%	0.02%	5.76%	0.00%	100.00%
x	3-month Treasury rate	4.95%	5.05%	1.63%	1.33%	8.54%
	Discount rate	4.72%	5.00%	1.50%	0.94%	7.00%
	Monetary base / required reserves	9.32	7.65	4.07	4.31	18.31
	System-wide loan growth	5.91%	6.34%	4.63%	-6.69%	16.50%
	Log real assets	11.85	11.72	1.25	8.11	19.74
	Baa – Treasury credit premium	1.99%	1.85%	0.50%	1.37%	3.59%
y	Discount rate	4.72%	5.00%	1.57%	0.94%	7.00%
	Non-pledged securities / assets	13.85%	11.30%	12.83%	0.00%	91.76%
	Growth of total loans	8.99%	7.00%	21.00%	-50.00%	100.00%
	Growth of core deposits	6.77%	4.21%	19.78%	-50.00%	100.00%
	FHLB access	2.65%	0.00%	6.44%	0.00%	35.00%
	Log real assets	11.31	11.20	1.16	7.46	19.74

Notes: This table reports summary statistics for the dependent and independent variables used in the regressions. The variable letters refer to equations (2) through (4). x is the vector of control variables used in the stage-one (supply curve) regression, with the individual interbank rate *r* as the dependent variable. y is the vector of control variables used in the stage-two (demand curve) regression, with interbank reliance *Q* as the dependent variable. Statistics for *r*, *p*, and the x variables are reported for the sample used in the stage-one estimation (164,708 observations). Statistics for the remaining variables are reported for the sample used in the stage-two estimation (341,541 observations).

Table IV

Summary Statistics for Interbank-Borrowing Rates, 1987:1 – 2002:4

	Average of Quarterly Averages	Average Quarterly Std. Dev.	Std. Dev. of Quarterly Averages
Effective fed-funds rate	5.42	0.26	1.95
Sample interbank rate:			
Full Sample	5.28	1.16	1.68
Banks < $1 bil in assets	5.33	1.18	1.62
Banks > $1 bil in assets	5.23	0.67	1.85

Notes: This table compares the time-series and cross-sectional variation of individual interbank rates calculated from Call Report data with the effective fed-funds rate. The sample includes 164,708 quarterly observations on commercial banks that borrowed in the interbank market (an average of 2,574 per quarter), after being screened according to the criteria described in Section III. The statistics for the effective fed-funds rate are calculated using daily data. The individual bank rates are calculated by dividing quarterly interest expense on interbank borrowing by the quarterly average of the daily quantity of these borrowings outstanding. The $1-billion cutoff is in 1996 dollars

Table V

Interbank Pricing Regressions (Supply Curves)

	Baseline	Discount rate instead of Treasury rate	Controls omitted, except Treasury rate	Treasury rate omitted
Intercept	0.632*** (0.034)	1.084*** (0.035)	0.311*** (0.009)	8.067*** (0.047)
Failure probability	0.003*** (0.0006)	0.004*** (0.0006)	0.005*** (0.0006)	0.020*** (0.0009)
3-month Treasury rate	1.040*** (0.002)		0.990*** (0.002)	
Discount rate		1.048*** (0.002)		
Monetary base / required reserves	-0.026*** (0.001)	-0.071*** (0.001)		-0.151*** (0.002)
System-wide loan growth	0.003*** (0.0008)	0.028*** (0.0008)		0.037*** (0.001)
Log real assets	-0.112*** (0.002)	-0.110*** (0.002)		-0.041*** (0.004)
Baa – Treasury credit premium	0.490*** (0.010)	0.498*** (0.010)		-0.597*** (0.014)
R^2	0.659	0.627	0.649	0.172
Observations	164,708			

Notes: This table reports regression results for equation (2), which specifies the supply of interbank funding. Because each bank is assumed to face a perfectly elastic supply curve, the regression takes the form of a price-determination equation, with the average quarterly rate paid by each bank on its interbank borrowing as the dependent variable. To show robustness, four alternative specifications are depicted in the table, with various regressors included and omitted. Standard errors are given in parentheses. Statistical significance at the 1% level is denoted by ***. The specification in the left-most column is the baseline. All variables are statistically significant with the anticipated signs in this model, and most of these results are robust to other specifications. Most importantly, the coefficient on SEER failure probability is positive and significant in every specification, although economically small. See Appendix B for additional robustness checks.

Table VI

Interbank Reliance Regressions (Demand Curves)

	Baseline: Equation (3)	Baseline without controls	Baseline + failure probability: Equation (4)
Intercept	-10.857*** (0.065)	1.731*** (0.019)	-10.861*** (0.065)
Estimated individual interbank rate	-0.095*** (0.013)	-0.061*** (0.003)	-0.079*** (0.013)
Discount rate	0.121*** (0.014)		0.107*** (0.014)
Non-pledged securities / assets	-0.020*** (0.0005)		-0.020*** (0.0005)
Growth of total loans	0.006*** (0.0003)		0.006*** (0.0003)
Growth of core deposits	-0.005*** (0.0003)		-0.006*** (0.0003)
FHLB Access	-0.003*** (0.0009)		-0.003*** (0.0009)
Log real assets	1.111*** (0.005)		1.112*** (0.005)
Failure probability			-0.014*** (0.001)
R^2	0.144	0.0009	0.145
Observations		341,541	

Notes: This table reports regression results for equations (3) and (4), which model banks' reliance on fed funds. The dependent variable is interbank borrowings over total assets. Equation (3), alternative specifications of which are shown in the first two columns, is a pure demand-curve estimation, using the forecasted value for the individual interbank rate r from the stage-one (supply-curve) regressions as a regressor. Equation (4) adds SEER failure probability as an additional regressor to pick up any quantity-rationing effects. Standard errors are given in parentheses. Statistical significance at the 1% level is denoted by ***. All variables are statistically significant with the anticipated signs in each specification. Most importantly, the coefficient on the individual interbank rate is negative and significant in each equation, and the coefficient on failure probability is positive and significant in equation (4). See Appendix B for additional robustness checks.

Table B-I

Alternative Demand Curves

	Tobit Model		*Net Purchases*	
	Controls included	Controls omitted	Controls included	Controls omitted
Intercept	-3.645*** (0.039)	1.731*** (0.019)	-22.736*** (0.117)	-2.077*** (0.036)
Estimated individual fed-funds rate	-0.040*** (0.008)	-0.061*** (0.003)	-0.152*** (0.024)	-0.222*** (0.006)
Discount rate	0.034*** (0.009)		0.029 (0.026)	
Non-pledged securities / assets	-0.014*** (0.0003)		-0.003*** (0.0008)	
Growth of total loans	0.002*** (0.0002)		0.039*** (0.0005)	
Growth of core deposits	-0.002*** (0.0002)		-0.025*** (0.0005)	
FHLB Access	0.001*** (0.0005)		0.083*** (0.002)	
Log real assets	0.382*** (0.003)		1.761*** (0.009)	
R^2			0.123	0.002
Observations		375,570		

Notes: This table shows alternative versions of the equation (3) regressions reported in Table VI. The dependent variable in the Tobit model is the ratio of interbank borrowing to total assets, as in the baseline model. In the "net purchases" specification, the dependent variable is the ratio of interbank borrowing *less* interbank loans to total assets. Both specifications are intended to deal with the zero-censoring of the unmodified interbank-borrowing variable. Standard errors are in parentheses. Statistical significance at the 1% level (using chi-squared tests for the Tobit regression and t tests for the OLS regression) is denoted by ***. In both equations, the basic conclusion of the baseline model holds, and all variables remain statistically significant with the predicted signs. In particular, both demand curves are downward sloping.

Table B-II

Fed-Funds Pricing with Alternative Ranges for Calculated Rates

	Size of band around effective fed-funds rate				
	50bp	100bp	200bp	400bp (baseline)	∞ (all obs.)
Intercept	-0.993*** (0.013)	-0.565*** (0.017)	-0.037 (0.024)	0.632*** (0.034)	10.313*** (3.219)
Failure probability	0.001*** (0.0002)	0.002*** (0.0003)	0.002*** (0.0004)	0.003*** (0.0006)	0.108* (0.055)
3-month Treasury rate	1.177*** (0.0009)	1.151*** (0.001)	1.096*** (0.002)	1.040*** (0.002)	1.809*** (0.203)
Monetary base / required reserves	-0.011*** (0.0005)	-0.014*** (0.0006)	-0.019*** (0.0009)	-0.026*** (0.001)	-0.376*** (0.120)
System-wide loan growth	0.009*** (0.0003)	0.009*** (0.0004)	0.006*** (0.0006)	0.003*** (0.0008)	0.086 (0.075)
Log real assets	-0.020*** (0.0009)	-0.051*** (0.001)	-0.078*** (0.002)	-0.112*** (0.002)	-1.274*** (0.224)
Baa – Treasury credit premium	0.386*** (0.004)	0.402*** (0.005)	0.439*** (0.007)	0.490*** (0.010)	3.734*** (0.915)
R^2	0.971	0.926	0.822	0.659	0.0008
Observations	72,200	113,102	146,649	164,708	178,769

Notes: To screen out data errors, the sample used in the regressions reported in the text excludes all observations that have computed interbank rates lying either below zero or outside of a 400-basis-point band around the effective fed-funds rate in each quarter. This table shows the results of the interbank-funding-supply estimation (equation (2)) under alternative restrictions on the range of admissible rates. Standard errors are given in parentheses. Statistical significance is denoted by * (10%) and *** (1%). Except in the completely unrestricted case, the coefficient sign and significance patterns are entirely consistent across the different samples. In particular, the coefficient on failure probability is always positive and statistically significant but economically small.

Table B-III

Bank Characteristics by Funding Choice (1988 – 1996)

	# obs.	SEER probability	Rate on interbank borrowing.	Interbank borrowing / assets	Total assets ($ millions)
FF banks	23,272	0.75% (5.26%)	5.28% (2.10%)	3.18% (5.79%)	366.4 (2,569.1)
Repo banks	33,690	0.75% (5.66%)	5.33% (1.98%)	3.22% (3.70%)	210.8 (1,096.6)
All banks	85,234	0.76% (5.48%)	5.45% (2.10%)	3.16% (4.66%)	401.0 (3,378.5)

Notes: This table compares banks that relied heavily on federal funds with those that relied heavily on repurchase agreements during the years 1988 through 1996, the only period for which these groups can be identified. A bank is classified as a "FF bank" or a "repo bank" if over 90% of its interbank borrowing is in one category or the other. The data are quarterly, and only banks with nonzero interbank borrowing are included. Other sample restrictions, as described in the text, are also imposed. Numbers reported in the table are sample averages with standard deviations in parentheses. No large differences in risk or cost of funds appear between the two groups.

Table B-IV

Interbank Pricing (Supply Curves) by Funding Choice

	Baseline (All years)	All banks (1988-96)	FF banks (1988-96)	Repo banks (1988-96)
Intercept	0.632*** (0.034)	-0.118 (0.087)	-0.330** (0.158)	-0.016 (0.134)
Failure probability	0.003*** (0.0006)	0.003*** (0.0007)	0.004** (0.001)	0.0006 (0.001)
3-month Treasury rate	1.040*** (0.002)	1.070*** (0.004)	1.112*** (0.007)	0.999*** (0.005)
Monetary base / required reserves	-0.026*** (0.001)	0.004 (0.005)	-0.046*** (0.009)	-0.001 (0.007)
System-wide loan growth	0.003*** (0.0008)	0.004*** (0.001)	0.023*** (0.002)	-0.015*** (0.002)
Log real assets	-0.112*** (0.002)	-0.129*** (0.003)	-0.083*** (0.006)	-0.136*** (0.006)
Baa – Treasury credit premium	0.490*** (0.010)	0.802*** (0.024)	0.623*** (0.046)	0.955*** (0.035)
R^2	0.659	0.680	0.694	0.700
Observations	164,708	85,234	23,272	33,690

Notes: This table reports the estimation of the supply-curve (equation (2)) estimation for subsamples of banks that relied heavily on either federal funds or repurchase agreements during the years 1988 through 1996. (The results for all banks during this period are reported for comparison.) A bank is classified as a "FF bank" or a "repo bank" if over 90% of its interbank borrowing is in one category or the other. The data are quarterly, and only banks with nonzero interbank borrowing are included. Other sample restrictions, as described in the text, are also imposed. Standard errors are reported in parentheses. Statistical significance is denoted by ** (5%) and *** (1%). The coefficient on risk is statistically insignificant for the repo banks. It is statistically significant (at the 5% level) for the FF banks and of roughly the same magnitude as in the baseline specification. This indicates that the presence of repurchase agreements in the data is not substantially contaminating the results.

Table B-V

Interbank Pricing with Alternative Measures of Bank Risk

		SEER (Baseline)	CAMEL(S) composite	SEER components	CAMELS components	CAMEL components
Summary Risk Measures	Failure probability	0.003*** (0.0006)				
	CAMEL(S) composite		0.042*** (0.009)			
Capital	Tangible capital			-0.001 (0.001)		
	CAMELS - C				-0.011 (0.020)	-0.006 (0.013)
Asset Quality	Loans 30-90 days past due			0.038*** (0.004)		
	Loans past due 90+ days			0.069*** (0.008)		
	Nonaccrual loans			0.026*** (0.004)		
	Other real estate owned			-0.046*** (0.005)		
	Commercial & industrial loans			-0.003*** (0.0005)		
	Residential real estate loans			-0.005*** (0.0003)		
	CAMELS - A				0.049*** (0.018)	0.029*** (0.011)
Earnings	Net income (ROA)			0.025*** (0.005)		
	CAMELS - E				-0.049*** (0.016)	-0.051*** (0.009)
Liquidity	Investment securities			-0.001*** (0.0003)		
	Large time deposits			0.008*** (0.0005)		
	CAMELS - L				0.097*** (0.018)	0.103*** (0.011)
Management	CAMELS – M				-0.011 (0.021)	0.020 (0.013)
Market Sensitivity	CAMELS - S				0.056*** (0.014)	
	R^2	0.659	0.684	0.661	0.603	0.685
	Observations	164,708	40,678	164,708	16,857	40,678

Notes: This table shows regression results for equation (2) using CAMELS composite scores as the risk measure and decomposing bank risk into its various components. Standard errors are given in parentheses. Statistical significance at the 1% level is denoted by ***. Control variables are included in the estimation but their coefficients are omitted below. The CAMELS results are similar to those using failure probabilities, and the most important sources of risk appear to relate to asset quality and liquidity.

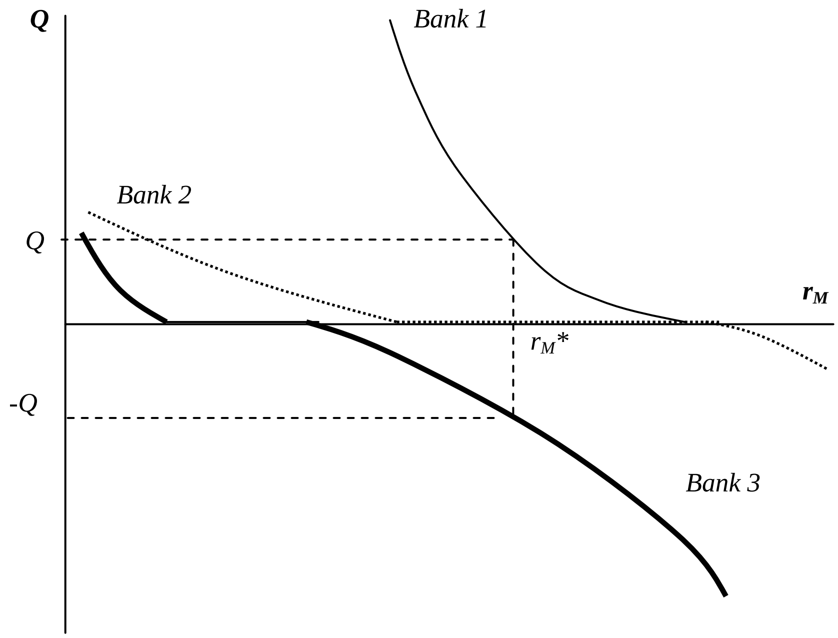

Figure 1. A competitive fed-funds market with three banks. This figure depicts fed-funds demand curves for an economy in which liquidity shocks are distributed normally and only three banks exist. The vertical axis shows net fed-funds purchases *Q* (negative values indicate sales). The horizontal axis shows the risk-free rate of interest r_M. Differences in overall liquidity shift the entirety of a bank's demand curve. Here, Banks 1 and 2 are assumed to have identical low levels of liquidity, and Bank 3 is assumed to have a high level of liquidity. Differences in default risk shift only the portion of the curve lying in positive territory, because an idiosyncratic risk premium applies to any borrowings. Bank 1 is assumed to have low risk, Bank 2 to have high risk, and Bank 3 to have an intermediate level of risk. The length of the flat portion of each bank's demand curve, representing the range of r_M over which it chooses not to buy or sell fed funds, is proportional to its risk. In this market, Bank 3 does all of the fed-funds lending, Bank 1 does all of the borrowing, and Bank 2 does not participate. The equilibrium risk-free rate r_M* is the one that clears this market.

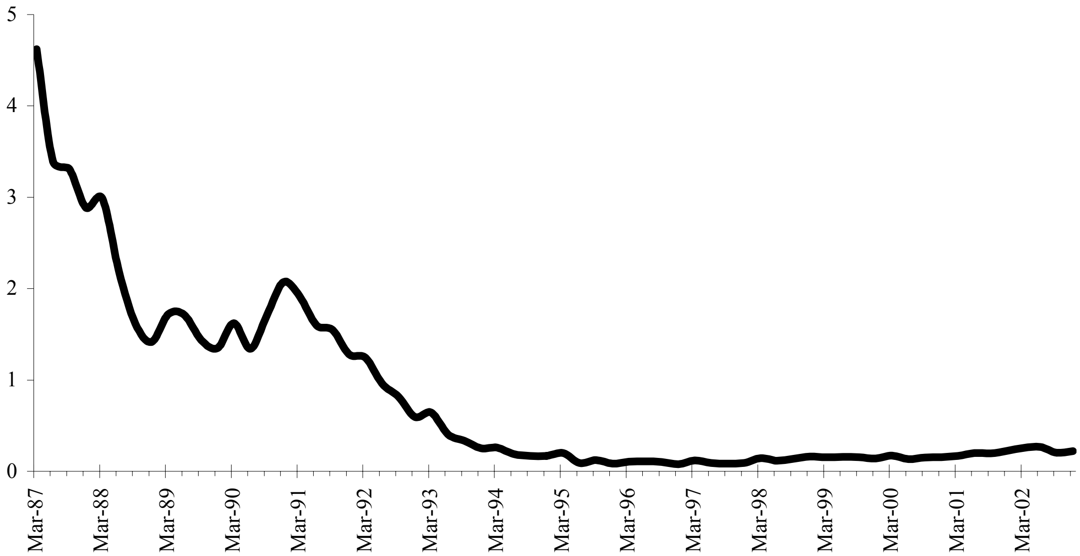

Figure 2. Average SEER-estimated one-year failure probabilities. This figure displays the quarterly sample averages of failure probabilities over each coming year, as computed using the Federal Reserve's System to Estimate Examination Ratings (SEER). These probabilities are used as the primary metric of default risk in the empirical tests of this paper, and their estimation is more fully described in Table II.

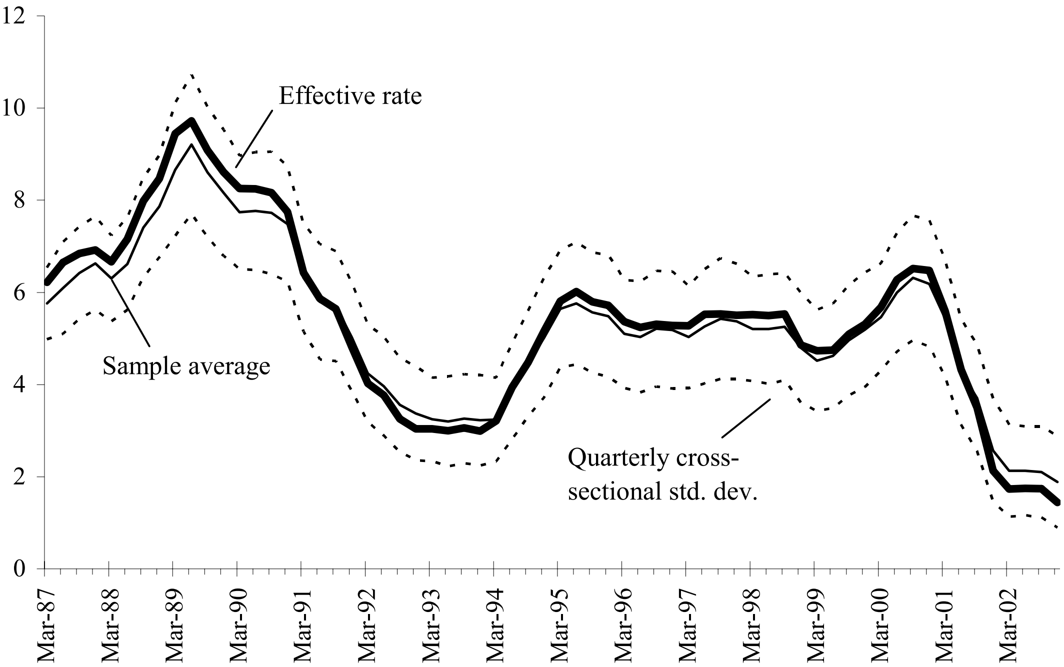

Figure 3. Comparison of effective federal-funds rate and sample interbank rate. This figure shows the quarterly average of the effective federal-funds rate (as reported by the Federal Reserve) and the quarterly average and quarterly cross-sectional standard deviation of the sample interbank-borrowing rates computed from the Call Report data. The sample includes 164,708 quarterly observations on commercial banks that borrowed in the interbank market (an average of 2,574 per quarter), after being screened according to the criteria described in Section III. The sample tracks the effective rate closely on average, but there is substantial variation across banks in the rates paid.

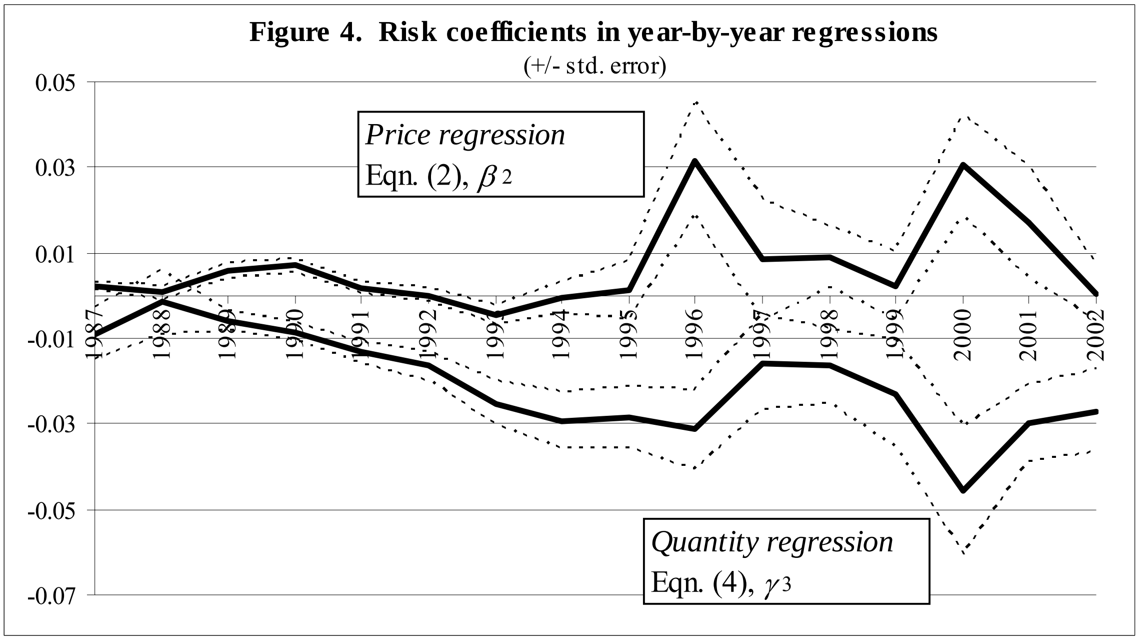

Figure 4. Risk coefficients in year-by-year regressions. This figure displays the coefficient on SEER failure probability in yearly estimations of equation (2), which has individual interbank borrowing rates as the dependent variable, and equation (4), which has interbank reliance as the dependent variable. All control variables listed in Table III are also included in these regressions. Dotted lines show standard-error bands. Both coefficients exhibit significant increases in magnitude in the mid 1990s. This finding is consistent with the theoretically predicted effects of legislation passed during that time that imposed more of the costs of bank failure on sellers of fed funds.

Notes

[1] Throughout this paper, I use the term "interbank" to refer to federal-funds and repurchase-agreement activity only; it should not be understood to include the (substantially fewer) transactions between banks that have durations of longer than a few days.

[2] Although precise numbers are not available, Meulendyke (1998, p. 85) estimates that a "thousand or so" banks regularly engage in transactions with brokers and that most of these transactions involve amounts of more than $25 million. By contrast, an average of 10,330 banks have participated in the interbank market at least once per quarter since 1987, and the vast bulk of these transactions were less than $25 million. This suggests that the majority of activity in the fed-funds market takes place through direct transactions or correspondent relationships, rather than through brokers.

[3] Flannery (1998) provides a review. More recently, see Bliss and Flannery (2001), Martinez Peria and Schmukler (2001), and Sironi (2003).

[4] See Section III for details on the data and construction of the variables.

[5] Billet et al. (2001) flesh out this liability-substitution theory in detail and provide some empirical evidence from the subordinated-debt market. Stojanovic et al. (2002) indeed find that riskier banks have a greater tendency to become FHLB members and to rely on FHLB advances.

[6] For well known examples, see Poole (1968) and Ho and Saunders (1985). More recently, see Bartolini et al. (2002) and Clouse and Dow (2002).

[7] For example, Allen et al. (1989) report the following case in a footnote: "In fall 1973, Morgan Guaranty refused to sell FF [fed funds] to Franklin National Bank, almost one year before the latter failed (in October 1974)."

[8] Banks are currently required to hold 3% reserves on transaction deposits over an exemption cutoff and 10% reserves on balances above a low-reserve cutoff. The dollar values of the cutoffs vary from year to year but, between 1987 and 2002, averaged $4 million and $45 million respectively, although the emergence of retail sweep accounts in the mid-1990s may mean that the cutoffs are, in effect, substantially higher (Anderson and Rasche, 2001). Over the same period, the average commercial bank held over $67 million in transaction deposits.

[9] Because gross purchases must be strictly non-negative, a disproportionate number of observations cluster at zero, making OLS a somewhat inappropriate specification. One way of dealing with this problem is to estimate a Tobit regression for gross purchases. Another alternative is to use net purchases (i.e., purchases less sales) as the dependent variable, effectively allowing some of the zero gross-purchase observations to spread out in the negative orthant. I report the results of both of these models in Section B1 of the appendix.

[10] The nature of this model—originally named the Financial Institution Monitoring System (FIMS)—is discussed in detail in Cole et al. (1995).

[11] SEER is estimated over a two-year horizon, but the interest rates to which I want to compare it are all reported on an annual basis. I therefore apply a constant-proportional-hazard-rate transformation to the SEER probabilities to obtain one-year figures. This adjustment turns out to make little qualitative difference in the regression results.

[12] Members of the FHLB system have nearly instantaneous access to a large line of credit on flexible terms, which can in some cases serve as a substitute for borrowing in the fed-funds market. The FHLB advances available to a bank, however, are capped according to the bank's size and collateral restrictions. Using these items, together with outstanding advances, it is possible to construct an approximation for the unused line of credit with the FHLB, and this is the variable included in the regressions under the name "FHLB access." For non-members, including all observations prior to 1992:4, when data on commercial banks first became available, this variable is set equal to zero. (Although membership first became available in 1989, very few banks became members before 1992.)

[13] On average, the Call Report figure is about 14 basis points lower than the effective fed-funds rate, but this may be partly due to the bid-ask spread contained in the rates on brokered transactions that are used to calculate the effective rate.

[14] By contrast, Furfine (2001a) uses a 50-basis-point band. I experiment with different sizes of this admissible range in Section B2 of the appendix. In general, the results are not sensitive to its value.

[15] Repos are still subject to the risk that the collateral may not be collectable. As described by Ringsmuth (1985) and Muelendyke (1998, p. 102), this was a non-trivial problem for some banks during the 1980s.

[16] The existing evidence on the disciplining effects of FDICIA is mixed. Goldberg and Hudgins (2002) argue that riskier thrifts had less access to jumbo CDs after the legislation passed. However, Hall et al. (2002) find only weak evidence of such effects for commercial banks. Sironi (2003) provides evidence of the discipline-enhancing effects of retreating from too-big-to-fail policies for European banks in the 1990s.

[17] In contrast, Gilbert et al. (2004) find that adding jumbo-CD yields computed from Call Report data to such a model does not improve its predictive accuracy.

[18] In reality, a bank's sources of short-term liquidity can depend heavily on its risk. The ability to borrow money in public markets is directly related to the market's perception of the probability that the money will be repaid, although this is not an issue in most cases, because it is rarely possible to generate substantial funds in negotiable-CD or subordinated-debt markets on such short notice. Funds advanced through the Discount Window and the FHLB—which are more likely to be quickly available—may only be issued contingent upon bank condition and the posting of collateral. Whether these considerations will affect the qualitative predictions of the model depends largely on the relative risk elasticities of the various alternative sources of liquidity. As it stands, the model assumes that all sources of liquidity other than the fed-funds market have risk elasticities of zero. Obviously, this an upper bound. If the elasticities are actually greater for other liabilities than for fed funds, increases in risk may force banks to substitute into interbank borrowing and thus increase reliance on fed funds, the opposite of what the model predicts. However, the empirical tests indicate that riskier banks tend to rely less on fed funds, suggesting that this effect is not of major importance.

[19] More generally, one could assume that excess reserves effectively earn a small positive rate, as is the case, for example, if they can be applied to qualifying reserve balances for the following reserve-maintenance period under a carry-forward rule. Allowing for this possibility complicates the analysis without adding much in the way of theoretical insight.

[20] Because all of the market transactions in the model are assumed to take place before any Discount Window borrowing, it is not possible for banks in the model to borrow from the Window in order to sell fed funds. Until the recent policy changes, Fed regulations explicitly prohibited this activity. In the new regime, it is no longer prohibited (because the Discount Window administrator is not allowed to ask any questions about the purpose of the borrowing), but it is still likely to be a rare occurrence because the primary-credit rate is set considerably higher than the effective fed-funds target.

[21] The control variables used in the baseline model are also included in the regressions reported in this table, but I do not report them in the table, to conserve space. They do not differ significantly from the values obtained in the other specifications.